Nanotribology and Surface Properties

Accurate determination of adhesive and frictional forces between surfaces and particles is critical for efficient and effective design and development of nanoscale devices and manufacturing processes. Working with diverse industrial partners (instrument, device, and magnetic storage industries), we are addressing this critical need by developing metrology tools and methods for nanomechanical property measurements.

Stephen M. Hsu and Richard S. Gates

One of the major conclusions from the National Nanotechnology Initiative workshop on instrumentation and metrology (held at NIST in January 2004) was need for improved tools, methods, and calibration procedures for nanoscale measurements. Several advances in measuring friction and adhesion and controlling surface lubrication and texturing were achieved this year.

Advances in Instrumentation

Existing atomic force microscopy (AFM) and multiscale friction testing instruments were upgraded to improve measurement accuracy and extend applicability of the methods. The AFM was extensively modified to increase the signal-to-noise ratio. A joint effort with Hysitron resulted in a new 3-D force sensor to conduct friction and scratch tests with much higher accuracy. Sample stage modulation is being implemented across several platforms to increase sensitivity and expand measurement capability. In-house cantilever and tip fabrication capability and collaborations with numerous specialty tip fabricators were established.

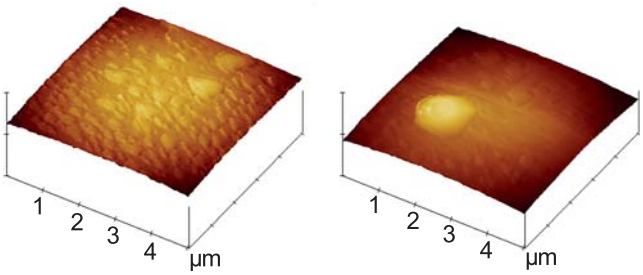

Figure 1: *Surface features on colloidal probes.*

In adhesion and friction measurements, surface forces are critical parameters that depend upon the real area of contact. Figure 1 illustrates typical colloidal probes showing random surface features. A computational procedure was developed to estimate the bearing area for this type of probe enabling better determination of contact areas.

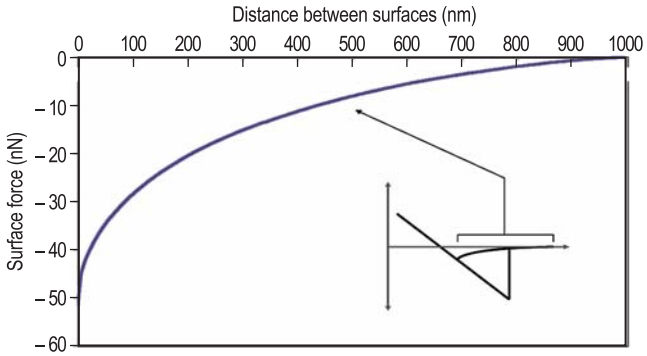

Figure 2: *Surface force measurement down to 1 nm. The inset shows a schematic of a typical force curve from the AFM.*

The first nanoscale probe using an ultra-thin sheet of mica glued on a colloidal probe was successfully developed to measure surface forces on extremely small areas (Figure 2). To avoid snap-on of the probe tip during approach, the cantilever stiffness and signal-to-noise ratio were increased.

Surface Control

Advances were made in the organization of mixed molecules on surfaces for hydrophobicity, anti-adhesion, and friction control properties. Ultra-durable hydrophobic films and friction control films were demonstrated last year. Collaboration with Dan Fischer at the NIST beam line at the National Synchrotron Light Source continues to be vital in characterizing these complex molecular mixtures.

Surface textures are increasingly being used to control surface energy, polarity, adhesion, and friction. In work supported by other agencies and industries, the surface properties of materials were controlled by use of specific surface features such as dimples, triangles, and ellipses at micro- and nanoscale dimensions.

Interactions

Ongoing interactions with domestic and international partners included a cantilever force calibration study with other National Measurement Institutes and Jon Pratt (NIST, MEL), and surface texture research with seven other countries.

Contributors and Collaborators

C. Ying, S. Yang, M. Reitsma, D.-I. Kim, Y. Liang, X. Wang, J. Grobelny, D. Fischer, Y.T. Hsia (Seagate); W. Gerberich (University of Minnesota); O. Warren (Hysitron); C. Su (Veeco); D. Mendel (NPL); E. Santner (BAM)